CHAPTER 4

EARTHWORK: EXCAVATION AND PREPARATION FOR FOUNDATIONS

4-1. Excavation.

a. General. In general, excavation for subsurface structures will consist of open excavation and shaft and tunnel excavation. Where excavation to great depths is required, a variety of soils and rock may be encountered at a single site. Soils may range through a wide spectrum of textures and water contents. Rock encountered may vary from soft rock, very similar to a firm soil in its excavation requirements, to extremely hard rock requiring extensive blasting operations for removal. Groundwater may or may not be present. The groundwater conditions and the adequacy of groundwater control measures are important factors in excavation, in maintaining a stable foundation, and in backfilling operations. The extent to which groundwater can be controlled also influences the slopes to which the open excavation can be cut, the bracing required to support shaft and tunnel excavation, and the handling of the excavated material.

b. Good construction practices, and problems. A majority of the problems encountered during excavation are related to groundwater conditions, slope stability, and adverse weather conditions. Many of the problems can be anticipated and avoided by preconstruction planning and by following sound construction practices.

(1) *Groundwater.* Probably the greatest source of problems in excavation operations is groundwater. If the seepage of groundwater into an excavation is adequately controlled, other problems will generally be minor and can be easily handled. Several points should be recognized that, if kept in mind, will help to reduce problems attributable to groundwater. In some instances, groundwater conditions can be more severe than indicated by the original field exploration investigation since field explorations provide information only for selected locations and may not provide a true picture of the overall conditions.

(*a*) If groundwater seepage begins to exceed the capacity of the dewatering system, conditions should not be expected to improve unless the increased flow is known to be caused by a short-term condition such as heavy rain in the area. If seepage into the excavation becomes excessive, excavation operations should be halted until the necessary corrective measures are determined and effected. The design and evaluation of dewatering systems require considerable experience that the contractor or the contracting office often do not possess, and the assistance of specialists in this field should be obtained.

(*b*) Groundwater without significant seepage flow can also be a problem since excess hydrostatic pressures can develop below relatively impervious strata and cause uplift and subsequent foundation or slope instability. Excess hydrostatic pressures can also occur behind sheet pile retaining walls and shoring and bracing in shaft and tunnel excavations. Visual observations should be made for indications of trouble, such as uncontrolled seepage flow, piping of material from the foundation or slope, development of soft wet areas, uplift of ground surface, or lateral movements.

(*c*) Accurate daily records should be kept of the quantity of water removed by the dewatering system and of the piezometric levels in the foundation and beneath excavation slopes. Separate records should be kept of the flow pumped by any sump-pump system required to augment the regular dewatering system to note any increase of flow into the excavation. Flowmeters or other measuring devices should be installed on the discharge of these systems for measurement purposes (TM 5-818-5/NAVFAC P-418/AFM 88-5, Chap. 6). These records can be invaluable in evaluating "Changed Condition" claims submitted by the contractor. The contractor should be required to have "standby" equipment in case the original equipment breaks down.

(2) *Surface water*. Sources of water problems other than groundwater are surface runoff into the excavation and snow drifting into the excavation. A peripheral, surface-drainage system, such as a ditch and berm, should be required to collect surface water and divert it from the excavation. In good weather there is a tendency for the contractor to become lax in maintaining this system and for the inspection personnel to become lax in enforcing maintenance. The result can be a sudden filling of the excavation with water during a heavy rain and consequent delay in construction. The surface drainage system must be constantly maintained until the backfill is complete. Drifting snow is a seasonal and regional problem, which can best be controlled by snow fences placed at strategic locations around the excavation.

(3) *Slope integrity*. Another area of concern during excavation is the integrity of the excavation

slopes. The slopes may be either unsupported or supported by shoring and bracing. The lines and grades indicated in the plans should be strictly adhered to. The contractor may attempt to gain additional working room in the bottom of the excavation by steepening the slopes; this change in the plans must not be allowed.

(*a*) Where shoring and bracing are necessary to provide a stable excavation, and the plans and specifications do not provide details of these requirements, the contractor should be required to submit the plans in sufficient detail so that they can be easily followed and their adequacy checked. The first principle of excavation stabilization, using shoring and bracing, is that the placing of supports should proceed with excavation. The excavation cut should not be allowed to yield prior to placing of shoring and bracing since the lateral pressures to be supported would generally be considerably greater after yield of the unshored cut face than if no movement had occurred prior to placement of the shoring. Excavation support systems are discussed in TM 5-818-1/AFM 88-3, Chapter 7. All safety requirements for shoring and bracing as contained in EM 385-1-1 should be strictly enforced.

(*b*) The inspector must be familiar with stockpiling requirements regarding the distance from the crest of the excavation at which stockpiles can be established and heavy equipment operated without endangering the stability of the excavation slopes. He must also know the maximum height of stockpile or weight of equipment that can be allowed at this distance.

(*c*) Excessive erosion of the excavation slopes must not be permitted. In areas subject to heavy rainfall, it may be necessary to protect excavation slopes with polyethylene sheeting, straw, silt fences, or by other means to prevent erosion. Excavation slopes for large projects that will be exposed for several seasons should be vegetated and maintained to prevent erosion.

(4) *Stockpiling excavated material*. Generally, procedures for stockpiling are left to the discretion of the contractor. Prior to construction, the contractor must submit his plans for stockpiling to the contracting officer for approval. In certain cases, such as where there are different contractors for the excavation and the backfill phases, it may be necessary to include the details for stockpiling operations in the specifications. In either case, it is important that the stockpiling procedures be conducive to the most advantageous use of the excavated materials.

(*a*) As the materials are excavated, they should be separated into classes of backfill and stockpiled accordingly. Thus the inspection personnel controlling the excavation should be qualified to classify the material and should be thoroughly familiar with backfill re requirements. Also, as the materials are placed in stockpiles, water should be added or the materials should be aerated as required to approximate optimum water content for compaction. Field laboratory personnel can assist in determining the extent to which this is necessary. The requirements of shaping the stockpile to drain and sealing it against the entrance of undesirable water by rolling with spreading equipment or covering with polyethylene sheeting should be enforced. This step is particularly important for cohesive soils that exhibit poor draining characteristics and tend to remain wet if once saturated by rains. Stockpiles must be located over an area that is large enough to permit processing and where they will not interfere with peripheral drainage around the excavation and will not overload the slopes of the excavation.

(*b*) In cases where significant energy and cost saving can be realized, special stockpiling requirements should be implemented. An example would be a large project consisting of a number of excavation and backfilling operations. The excavation material from the first excavation could be stockpiled for use as backfill in the last excavation. The material from the intermediate excavations could in turn be immediately used as backfill for the first, second, etc., phases of the project and thereby eliminate double handing of excavated backfill for all but the first-phase excavation.

(5) *Protection of exposed material*. If materials that are exposed in areas, such as walls of a silo shaft, foundation support, or any other area against which concrete will be placed, are susceptible to deterioration or swell when exposed to the weather, they should be properly protected as soon after exposure as possible.

Depending on the material and protection requirements, this protection may be pneumatic concrete, asphalt spray, or plastic membrane (TM 5-818-1/AFM 88-33, Chap. 7). In the case of a foundation area, the contractor is required to underexcavate leaving a cover for protection, as required, until immediately prior to placement of the structure foundation. Any frost-susceptible materials encountered during excavation should be protected (para 2-3h (3) and (4)) if the excavation is to be left open during an extended period of freezing weather.

(6) *Excavation record*. As the excavation progresses, the project engineer should keep a daily record of the type of material excavated and the progress made. This record would be of value if subsequent claims of "Changed Conditions" are made by the contractor.

4-2. Foundation preparation.

a. General. In this manual, preparation applies to foundations for backfill as well as those for structures to be placed in the excavation. Generally, if proper excavation procedures have been followed, very little

additional preparation will be required prior to backfill placement.

b. Good construction practices, and problems. As mentioned previously, the problems associated with foundation preparation are greatly reduced by following such proper excavation procedures as maintaining a dry excavation and planning ahead. The principles of good foundation preparation are simple, but enforcing the provisions of the specifications concerning the work is more difficult. Inspection personnel must recognize the importance of this phase of the work since, if not properly controlled, problems can result.

(1) It is most important that a stable foundation be provided. Thus it may be necessary, particularly in the case of sensitive fine-grained materials, to require that the final excavation for footings be carefully done with hand tools and that no equipment be allowed to operate on the final cut surface. To provide a working platform on which to begin backfill placement on these sensitive materials, it may be necessary to place an initial layer of granular material.

(2) If the foundation is to be supported on rock, the soundness of the exposed rock should be checked by a slaking test (soaking a piece of the rock in water to determine the resulting degree of deterioration (para 3-2b (6)) and visual observation to determine if the rock is in a solid and unshattered condition. If removal of rock below the foundation level is required, the space should be filled with concrete. A qualified geological or soils engineer should inspect the area if it is suspected that the material will deteriorate or swell when exposed to the weather. If necessary, the materials must be protected from exposure using the methods previously discussed in paragraph 4-1b (5).

(3) Before placement of any structure foundation is begun, the plans should be rechecked to ensure that all required utilities and conduits under or adjacent to the foundation have been placed, so that excavating under or undermining the foundation to place utilities and conduits will not become necessary later.

(4) Occasionally, it may be found upon completion of the excavation that if a structure were placed as shown on the plans, it would be supported on two materials with drastically different consolidation charactertistics, such as rock and soil, rock and backfill, or undisturbed soil and backfill. This situation could occur because the predesign subsurface information was inadequate, because the structure was relocated or reoriented by a subsequent change in the plans, because of an oversight of the design engineer, or because of the excavation procedures followed by the contractor. Regardless of the reason, measures such as overexcavation and placement of subsequent backfill should be taken, where possible, and in coordination with the design office to provide a foundation of uniform material. Otherwise, the design office should evaluate the differences in foundation conditions for possible changes to the structural foundation elements.

(5) Preparing the area to receive the backfill consists of cleaning, leveling, and compacting the bottom of the excavation if the foundation is in soil. All debris and foreign material, such as trash, broken concrete and rock, boulders, and forming lumber, should be removed from the excavation. All holes, depressions, and trenches should be filled with the same material as that specified to be placed immediately above such a depression, unless otherwise designated, and compacted to the density specified for the particular material used. If the depression is large enough to accommodate heavy compacting equipment, the sides of the depression should have a positive slope and be flat enough for proper operation of compaction equipment. After the area is brought to a generally level condition by compacting in lifts in accordance with specifications, the entire area to receive backfill should be sacrificed to the depth specified, the water content adjusted if necessary, and the area compacted as specified. If the foundation is in rock, the area should be leveled as much as possible and all loose material removed.

(6) All work in the excavation should be accomplished in the dry; therefore, the dewatering system should be operated for the duration of this work. Under no circumstances should the contractor be allowed to dry an area by dumping a thick layer of dry material over it to blot the excess water. If soil exists at the foundation level and becomes saturated, it cannot be compacted. The saturated soil will have to be removed and replaced or drained sufficiently so that it can be compacted. Any frozen material in the foundation should be removed before placement of concrete footings or compacted backfill.